Using an Agent-based Model to Explore Troop Surge Strategy

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Using an Agent-based Model to Explore Troop Surge Strategy

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Abstract

In October of 2001, the United States invaded Afghanistan and replaced the Taliban government. Since its overthrow, the Taliban has pieced together and waged an insurgency to retake Afghanistan, and that insurgency has gained momentum and grown in strength while the United States/North Atlantic Treaty Organization (NATO) effort shrank in size to about 55,000 troops in 2007. A wide range of factors contributed to the insurgency, ranging from socio-cultural to economic to political. This research applied an in-depth study of Afghanistan to an agent-based model to determine if a military troop surge emphasizing a focused security effort could be successful in battling the growing insurgency within Afghanistan. An agent-based model was created and validated against the strategy and situation on the ground in Afghanistan that existed in 2007. Three experiments were conducted representing surges of 50%, 200%, and 400%. The results indicated that a surge of 200% or greater of the existing size force would be necessary to reduce the size of the insurgency, but that a surge of only 50% (50,000 more troops) would not bring about any significant changes as compared to the existing strategy. These model results provide insight into the potential success of various sized troop surges in Afghanistan that implement a focused security effort.

Keywords

Afghanistan, agent-based modeling, insurgency, Taliban

1. Introduction

In a September 2008 telephone interview, Afghan president Hamid Karzai was asked if he supported or thought that additional American troops in Afghanistan as part of a troop surge would serve a useful purpose. Karzai replied, '... of course, an increase in the troops of the international community in Afghanistan to focus on the war against terrorism is important.'[1] The Naval Postgraduate School's Program for Culture and Conflict Studies noted that from 2006 to 2007 security incidents increased 17%, suicide attacks increased 42%, and improvised explosive device attacks increased 9%.[2] An expanding and increasingly successful insurgency has been gaining momentum in Afghanistan since early 2002. Included among the insurgents is the Neo-Taliban. (For the purposes of this study, Neo-Taliban refers to all of the insurgent groups that are currently fighting against the United States/North Atlantic Treaty Organization (NATO) forces and the Afghan government. These groups include the old Taliban, former warlords hoping for a share of any new government of Afghanistan, those involved in the drug trade, those Afghans who fight to expel foreign troops, Pashtuns who fight to restore Pashtun majority rule and traditions, and any and all foreign jihadis, to include Al-Qaeda, who come to Afghanistan to fight against the West.)

Almost immediately after their defeat post the United States invasion in 2001, the Taliban began a patient and deliberate rebuilding of their movement from their sanctuary in the tribal areas of Pakistan to re-establish them in Afghanistan. In many areas of Afghanistan, Neo-Taliban governments exist alongside the constitutional Afghan governments and they

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control the lives of the citizens, 'dispensing Shari'a justice, mediating tribal and land disputes, collecting taxes, and recruiting, arming, and training fighters.'[3]

The International Security Assistance Force is the coalition of international troops in Afghanistan charged with countering this insurgency as part of the global war on terror and building a new, stable Afghanistan. These troops number nearly 55,000 soldiers (2007) with an area of responsibility of approximately 650,000 square kilometers, which is about one soldier for each 12 square kilometers of Afghanistan. That number itself can be misleading, in that for every soldier that engages with the Afghan public by conducting patrols, searching for insurgents, or trying to build roads, schools, or clinics, there is roughly one and a half soldiers who stay within the confines of secured bases cooking food, repairing equipment, analyzing intelligence, or managing operations.[4]

This begs the question: what more could be done to combat the complex problems facing Afghanistan? Would a military surge be effective? And just how many more troops would be needed to create success? In 2007 there was mixed opinion in the United States. Some in the Pentagon believed that a surge strategy is all that is needed to bring about a stable, secure Afghanistan and contain the insurgency, and some said it simply would not work. United States' Defense Secretary Robert Gates called for a surge of troops in November of 2008 stating, 'The violence is up [and] it's clear there is a need for more [troops] to try to deal with this increased security problem.'[5] A Washington Times article in 2008 states that 'several military and Afghanistan analysts say a surge there will not solve and could even worsen the problems of a country famous for resisting foreign interference.'[6]

The purpose of this research is to apply agent-based modeling as a way to assess whether a military surge in Afghanistan would be effective at mitigating the insurgency, while facilitating rebuilding of the state. The model seeks to answer three questions.

- Would a surge emphasizing a focused security effort shield the assets necessary for institutional reconstruction? Assets in areas such as health care (clinics), education (schools), infrastructure (roads, telecommunications), utilities (electric power stations, water supply), and local security (police) are the institutions necessary for a civil society.
- Would an improved security climate sway the loyalties of scared, war weary citizens of Afghanistan towards supporting its democratically elected central government?
- Is there a 'tipping point' for the size of a military surge that might reduce the size of and bring success against the insurgency in Afghanistan? Would 50,000 additional troops do the job? 100,000 additional troops? 300,000 additional troops?

This research proffers an agent-based simulation that models the complex interactions within Afghanistan that contribute to that country's ongoing insurgency. Agent-based models have been evaluated as useful tools in modeling and simulating complex social interactions among large populations. The premise of agent-based modeling is that through the interaction of intelligent agents, overall macroscopic behavior can be determined in a society or population. In this research an agent-based model attempts to capture resultant societal behavior by allowing individual agents to interact on a microscopic level over time. The model creates various agents that are responsible for the growth of the current insurgency in Afghanistan and the failure of the Afghan government and coalition forces to succeed in the business of nation and state building. A simulation then examines the resultant behavior from the interaction of the agents.

2. Modeling methodology

This section discusses the formulation and the details of the agent-based model used for the simulation. It will detail the factors that lead to the creation of agents and the motivation behind their interactions and rule sets. It also discusses the verification and validation of the model and it concludes with the results of the simulation implementing the surge parameters.

2.1 Model of Afghanistan insurgency

The first step in the modeling approach was to develop a conceptual model of the factors and relationships governing the Afghanistan insurgency and its relationship to the existing government and coalition troops. These factors and relationships are depicted in Figure 1. The derivation of this model is explained below.

Causal loop diagrams are derived from the study of system dynamics. They aid in representing how interrelated variables interact in a complex feedback manner. The diagram contains nodes that represent variables in a system and links (arrows) that show how these variables influence one another in a positive or negative manner. As an illustration, consider the block in Figure 1 representing the number of insurgents. As this number increases the number of insurgent attacks is likely to increase, causing insurgent collateral damage to increase and trust in government to decrease. The level of trust in government will influence civilian antipathy, which in turn may cause the number of insurgents to change.

How can a modeled and implemented counterinsurgency strategy, specifically a surge emphasizing a focused security effort, be measured as effective or ineffective? One such measure could be the change in the total number of insurgents over time. While this measure may not account for all measures of effectiveness, it is an indicator of how the strategy is achieving the high-level goal of insurgent reduction. Since the initial ouster of the Taliban in 2001, the

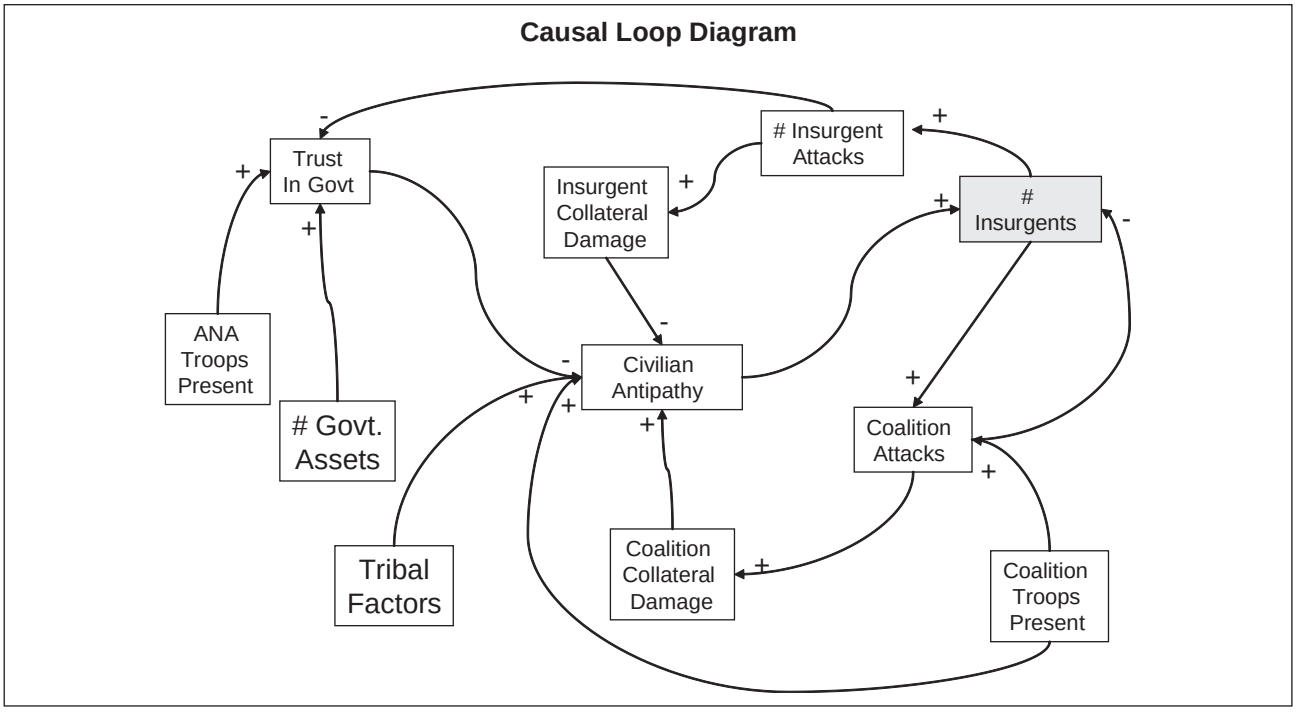

Figure 1. Conceptual model of Afghanistan insurgency. ANA: Afghan National Army.

number of insurgents has grown from an estimated 5500 in 2002 to 19,000 in 2006, lending credence to the argument that the war effort has not produced the success needed to stabilize and secure the state.[7] Any successful strategy will reduce the number of insurgents, be it through improvement in governance, reconstruction, or security, or any combination of these factors. Thus the number of insurgents becomes the model's dependent variable.

Insurgents come primarily from the civilians within Afghanistan. This simulation makes the assumption that civilians within Afghanistan become insurgents based on their level of antipathy towards the state. A civilian's antipathy toward the state depends upon several factors.

- **Foreign occupation** – this factor accounts for the Afghan's historical distaste for any foreign occupation and their religious duty to resist non-Muslim influence. Rais[8] stated, 'The neo-Taliban forces are no different in terms of social composition; they are essentially Pashtuns inspired by their glorious tradition of resistance against foreign forces and those who cooperate with them. Today's conflict in Afghanistan is no different in its essential structure than the one during the Soviet war in the popular Pashtun imagination; foreign forces occupying the country, supporting a regime constructed by it. The present Taliban force is built around Afghan nationalism and its driving force is Pashtun ethnicity more than it was before the American war.'
- **Trust in government** – this factor accounts for a citizen's overall belief in whether the current government can provide a stable, secure environment with basic services or whether the insurgency appears to be poised to overthrow the current government. Giustozzi[7] commented, 'It is apparent that much of the source and cause of the insurgency is the 'intrinsic weaknesses of the Afghan state. Over and over it is documented of local strongmen and warlords doing their own thing in regards to the administration of justice and economy which lends itself towards the relative lack of any sort of loyalty to the state.' Also included within this factor is the economic environment that can contribute to a civilian's decision to support the insurgency. One of the consequences of the lack of security within Afghanistan is the extreme poverty and lack of economic hope that pervades the country. Afghanistan ranks third poorest in the world economically.
- **Coalition collateral damage** – collateral damage caused by the coalition or Afghan National Army troops. This factor accounts for the damage and resentment caused by the collateral damage inflicted by the coalition or Afghan National Army soldiers in their pursuit of insurgents. Crews and Tarzi[9] comment on this factor by stating that 'along with house-to-house searches, air strikes that failed to distinguish friend from foe turned many Afghan communities against foreign troops and the Afghan leader they backed in Kabul.'

- **Insurgent collateral damage** – this factor represents the backlash towards the insurgents for the death and destruction caused by their attacks on the government or coalition or even upon the civilian population. For much the same reason that unintended casualties turn Afghans against the coalition, insurgent tactics and collateral damage can cause civilians to support the coalition.
- **Ethnic factors** – this factor represents the ethnic/tribal friction that exists within Afghanistan. The traditional rivalry that exists between the ethnic groups can contribute to a citizen's decision to support the insurgency, especially if they are isolated from other members of their tribe. Many times members of one tribe who serve in district or provincial governments will exclude members of other tribes and provide favors and benefits to only one segment of a population. Giustozzi[7] illustrates the tribal factor when he states, 'Noorzais of Kandahar and the Achakzais of Kandahar - the Achakzais' military leaders had control of Spin Boldak post 2001 and they ran the border police. They extracted illegal taxes from travelers and branded their rival Noorzais of being Taliban, effectively pushing them to the opposition.'

As any of these events occur, they affect a civilian's antipathy level, which is assigned to each civilian agent in the model upon creation according to a uniform distribution. Since we have no direct measure available for the actual distribution, the uniform distribution was chosen as one possible representation. As a civilian's antipathy level reaches a threshold, that civilian becomes an insurgent.

The level of trust in government, which is a significant factor of any civilian's antipathy, is determined by the presence of government assets, the presence of Afghan National Army troops, and the number of insurgent attacks. Government assets are created by Provincial Reconstruction Teams and they represent the tangible improvements in the three mandated areas for the teams: governance, security, and reconstruction. The assets include improvements in the administration of local government, the actual ethos and practical application of government, police and security, agriculture, medicine, education, electrical grids, transportation, the construction of schools, clinics, and police stations, and the overall improvement to the security situation within the area where the teams are working.

The presence of Afghan National Army troops represents a visible manifestation of a state that can improve security and prevent insurgent violence. This presence creates hope and trust in the government. Conversely, insurgent attacks decrease a citizen's trust in his government. By reinforcing the perception that the government is weak and cannot secure its people, the number of insurgent attacks influences the way Afghanis feel about their government. It creates the doubt that the government can defeat the insurgency and that eventually, it will be better to have been a supporter of the insurgents.

The next step in creating the Afghanistan model was to determine agent creation for the model. To represent the situation within the country, agents were created that represented the actors present and contributing to the overall environment. Several agents will participate in the model: civilian agents, coalition agents, Afghan National Army agents, insurgent agents, Provincial Reconstruction Team agents, government asset agents, terrain agents, and quick-reaction force agents. These agents, with a programmed set of rules based on the causal loop diagram, interact within a two-dimensional grid environment, representing a typical area within Afghanistan.

For this study, the grid is based on a generic area within the Khost province of Afghanistan that is 50 square kilometers or roughly seven kilometers by seven kilometers. Each square within the model grid will represent one tenth of a square kilometer to produce a final grid dimension of 70 squares by 70 squares. Khost sustains a population of approximately 487,000 people and the area modeled will contain approximately 5800 people. Of the entire population within the modeled area, only military age males (age 15–50) were represented, which make up approximately 23% of the population, or about 1300 men.[10] The population within Khost is 99% Pashtun and 1% Tajik, so upon creation, each civilian is randomly assigned a tribal affiliation with 99% being Pashtun and 1% being Tajik.[2] This area was chosen to be small enough to meet computational limitations, but large enough to be representative of the major conflict areas in Afghanistan.

2.2 Agent representation

The following sections describe the agents that are included in the model. It contains the motivation for their inclusion, their rule sets, and the logic behind each rule set.

2.2.1 Civilian agent. This type of agent represents the Afghan public and citizenry at large. The civilians are the most important agents within the model because it is for their hearts and minds that the insurgent and coalition efforts focus. The model is initialized with 1300 civilians on the grid. Each civilian is created with a tribal affiliation parameter of Pashtun (99%) or Tajik (1%) and a random amount of an antipathy parameter from one to 65 determined by a random draw from a uniform distribution. See Table 1 for a list of distributions used within the model. During a turn (in this model, a turn refers to a discrete time step; each time step lasts for the same simulated duration and during each time step, each agent within the model is given the opportunity to execute its instructions and follow its rules) each civilian within the simulation operates according to a set of rules as follows:

Table 1. Validation results.

Parameter	Value
Sample size	30
Sample mean	4.3
Sample standard deviation	2.184
z-statistic with $\mu_0 = 4$	0.752

1. Civilian agent searches the grid within its detection range (*civilianDetectionRange*) for other agents;
2. Check to determine if the tribal isolation counter has reached the threshold value – if it has, then add to that civilian's overall antipathy;
3. Calculate the total antipathy for this civilian – the formula for calculating the overall antipathy is as follows:
   A = antipathy;
   $A_{\text{Coalition}}$ = antipathy added due to coalition presence;
   $A_{\text{C Coaltion}}$ = antipathy added due to coalition collateral damage;
   $A_{\text{I Collateral}}$ = antipathy added due to insurgent collateral damage;
   A_{Tribal} = antipathy added due to tribal factors.
4. Check to determine if this civilian has reached the antipathy threshold, *antipathyThreshold*.

2.2.2 Insurgent agent. The next agent modeled is the insurgent agent. The increase, decrease, or leveling out of the number of insurgents represents the measure used within this study to determine if a surge emphasizing a focused security effort is successful. The model is initiated with *insurgentPopulation* number of insurgents. This number is based on the qualitative research on the overall estimate of the number of insurgents within Afghanistan scaled relative to the size of the area being modeled, starting in 2002. Giustozzi[7] estimated the total number of insurgent in Afghanistan as follows:

2002 – 5500;
2003 – 8000;
2004 – 10,200;
2005 – 13,700;
2006 – 19,000.

Insurgents search out targets within the grid during the simulation, moving towards and attacking the highest priority target. The priority of targets for insurgents is government assets, Provincial Reconstruction Teams, Afghan National Army, coalition forces. When attacking, insurgents have a probability of *insurgentCollateralDamageProbability* to cause collateral damage, which decreases civilian antipathy towards the government. In addition, when attacking, insurgents have different probabilities of success depending upon the type of target, with government assets being the easiest target and coalition forces being the most dangerous target.

During a turn each insurgent agent within the simulation follows a set of rules as follows.

1. Search the grid within its detection range (*insurgentDetectionRange*) for other agents.
   a. If there is a government asset detected, the insurgent must determine if there is another government asset already targeted. Government assets are the highest priority target for insurgents.
   b. As long as there is not a higher priority target, the insurgent checks for a Provincial Reconstruction Team target, which is priority two for insurgents.
   c. As long as there is not a higher priority target, the insurgent checks for an Afghan National Army target, which is priority three for insurgents.
   d. As long as there is not a higher priority target, the insurgent checks for a coalition target, which is priority four for insurgents.
2. Insurgents next check to see if there has been a target set.
   a. If no target has been set, the insurgent moves randomly within the environment.
   b. If a target has been set, the insurgent then checks to see if the target is within range (*insurgentWeaponRange*).

2.2.3 Coalition agent. These agents represent all foreign troops inside of Afghanistan that support the United States/NATO counterinsurgency effort. These agents hunt for and attack all insurgent agents found during the simulation. When an insurgent is found, a coalition agent will attack it. Each attack has a probability of success and a probability of causing collateral damage. A successful attack removes that insurgent agent. Collateral damage caused by a coalition agent increases nearby civilians' antipathy toward the government.

During a turn, each coalition agent operates with the following set of rules.

1. Coalition agent searches the grid within its detection range (*coalitionDetectionRange*) for other agents.
   a. If there is an insurgent detected, the coalition agent must determine if there is another insurgent already targeted.
   b. If no insurgent has been detected, then there will be no target set.

2. Coalition units next check to see if there has been a target set.
    a. If no target has been set, the coalition unit moves randomly within the environment.
    b. If a target has been set, the coalition unit fires at the target. Upon shooting at the target, a determination of whether collateral damage has occurred is made. If collateral damage has occurred, it is added to the terrain. Coalition units cause collateral damage with a probability of *coalitionCollateralDamageProbability*. The amount of collateral damage that is added is a random amount drawn from a normal distribution with a mean of 0.75 and a standard deviation of 0.005.

2.2.4 Provincial Reconstruction Team. The next agent introduced into the model is the Provincial Reconstruction Team. These agents are the entities on the ground in Afghanistan that have a mandate to facilitate reconstruction, good governance, and security. The concept behind the Provincial Reconstruction Teams is that these self-securing, 80–500-man teams move throughout the countryside and work to create improvements in their areas of expertise that are placed in the environment in the form of government assets. It takes a given number of turns (30 turns representing 30 days (*prtWorkCycle*)) for the teams to create their improvements. If the Provincial Reconstruction Team is attacked it will attempt to defend itself and call for a quick-reaction force of coalition military forces that will arrive during the next turn to fight the insurgents. If the team is successful in defending itself from the initial attack, it will continue work on its project unhindered. If the team is unsuccessful in defending itself, any work that it is doing must start over. In addition, if the team is idle upon encountering an insurgent, that team will attempt to move away from the insurgent but will still call for the quick-reaction force.

These teams are an essential part of the focused security effort strategy proposed by this research. The work performed by these teams leads to an increase in the Afghan citizenry's trust in government, which is essential to creating a society less inclined to rebel against its current government. The work done by these Provincial Reconstruction Teams includes working with local governments to improve the administration and services provided by those governments.[8] It also includes working with farmers to improve the agricultural output per farmer and to provide farming equipment. Reconstruction work done by these teams includes but is not limited to building roads, bridges, clinics, schools, and police stations. To improve security, the Provincial Reconstruction Teams work with local police and security forces to improve their overall quality to allow for improved security for Afghanis.

All of the work done by the Provincial Reconstruction Teams helps to improve one vital area that is covered under the umbrella of trust in government for this study: the economic wellbeing of the citizens of Afghanistan. With improved security, governance, and reconstructing the country, Afghan citizens are free to pursue their economic goals and wellbeing. Left unhindered by a corrupt government or crippled by a non-existent security environment, free and increasingly educated Afghanis will be able to improve their economic circumstances. This improvement will decrease the likelihood of poverty being a contributing factor to the insurgency.

During a turn, each Provincial Reconstruction Team operates with the following set of rules:

1. The team first checks if it has been attacked, and if so it calls for a quick-reaction force;
2. Next the team checks to see if it is idle:
    a. If the team is idle and not working on a project it searches within its search range (*pRTDetectionRange*) to determine if a government asset is found;
    b. If the team is not idle and is currently working on a government asset, it checks to determine if the work is complete.

2.2.5 Government assets. Government assets represent the tangible improvements created by the Provincial Reconstruction Teams. In the real world these assets represent buildings, such as clinics or schools, and in other cases they will represent hard-to-quantify improvements, such as the more efficient operation of local government, government services, more effective police, better farming or irrigation techniques, or improved security. In the model, government assets improve the citizens' lives and thus their trust in government within a radius of the asset, *assetInfluenceRange*.

As part of the strategy of a focused security effort, emphasis is placed on securing the improvements and progress of the government assets, using the extra surge troops to actively prosecute insurgents. Therefore, as part of any surge of troops within Afghanistan, platoon-sized elements will be stationed with the placement of the government assets. This is modeled by making the assets more difficult to destroy and giving them a defensive capability to signify the stationing of troops with the assets in remote locations.

During a turn, each government asset agent operates with the following set of rules:

1. The asset searches the area around it for other agents:
    a. If the agent found is a terrain agent, then add asset influence to that terrain one time out to a radius of *assetInfluenceRange*;
    b. If the agent is not terrain, do nothing.

2. Next, search the area immediately beside the asset for insurgents:
    a. If an insurgent is found then fire a defensive shot at the insurgent;
    b. If no insurgents are found, then do nothing.

2.2.6 Afghan National Army. These agents represent the military and security arm of the Afghan government and are the forces produced and fielded by the Karzai central government to engage the insurgency. The overarching mission of the Afghan National Army, as agreed upon by the participants of the Bonn II conference, is to:

- provide security for the central government and protect the political process as defined by the Afghan Constitution;
- replace every other militia and organized military force in the country;
- fight insurgents and terrorists; and
- work closely with coalition and other international forces.[11]

Within the model, these agents move within the environment and search for insurgent agents. Upon finding insurgents, the Afghan National Army agents attack them, and during their attack have a probability to cause collateral damage, *anaCollateralDamageProbability*. In addition, their presence bolsters civilian agents' trust in the government.

During each turn, each Afghan National Army agent operates according to the following set of rules:

1. The unit searches the area around it for other agents:
    a. If the agent found is an insurgent agent, then determine if there is already an insurgent agent targeted;
    b. If the agent is not an insurgent, do nothing.
2. Next, determine if a target has been set:
    a. If a target has not been set, then move randomly;
    b. If a target has been set then take a shot.

2.2.7 Quick-reaction force. This agent represents the forces within the United States/coalition force structure that are called upon whenever there is an attack that needs to be quickly reacted to. This quick-reaction force usually operates on a stand-by basis, often riding to the battle on helicopters to facilitate speed of response. The quick-reaction force is controlled by a force commander, usually at the battalion task force level or above, and is called upon whenever an attack occurs against a non-governmental agency, a friendly unit that cannot defend itself adequately, or if a unit is in danger of being overrun.[12]

Within the model, the quick-reaction force is called whenever a Provincial Reconstruction Team is attacked by an insurgent force. The force arrives on the scene of the attack and attempts to destroy the insurgent force. If successful, the insurgent force is destroyed and removed from the model. If it is not successful, the insurgent is moved away from the scene to simulate the withdrawal and dispersal of the insurgent unit back into the countryside.

During a turn, each quick-reaction force operates according to the following set of rules.

1. Move the quick-reaction force to the location of the reported attack.
2. Search for insurgents around the quick-reaction force. Is insurgent found?
    a. If insurgent is found, then determine if another insurgent is already targeted;
    b. If no insurgent is found, go home.
3. Is there a target set?
    a. If there is not a target set, then the quick-reaction force goes home.
    b. If there is a target set, then take a shot. The quick-reaction force hits with a probability of *qrfHitProbability*. Is the shot a hit?
        i. If the shot is a hit, then the insurgent is destroyed and removed. The quick-reaction force goes home and a determination is made if there has been collateral damage. The quick-reaction force causes collateral damage with a probability of *coalitionCollateralDamageProbability*.
        ii. If the shot is a miss, then move the insurgent away to a random location on the grid to simulate the ending of the attack and the withdrawal and dispersal of the insurgent force. Make a determination if there has been collateral damage caused.

2.2.8 Terrain. The final agent is the terrain agent. The purpose of this agent is to hold and store collateral damage, attack influence, and asset influence. By holding these values, terrain agents allow civilian agents to receive the effect of collateral damage, attack influence, and asset influence as they move throughout the environment. The only action performed by terrain agents is to decay the values of collateral damage and attack influence over time.

Collateral damage caused by either the coalition forces or the insurgent forces is placed on the terrain and decays over time according to an exponential decay function. This simulates the average person's memory of an attack, as well as an attack having the potential to affect nearby civilians and not having as big of a probability of affecting civilians at a distance. Collateral damage has a direct impact on a civilian's level of antipathy. Any civilian can only be affected by an attack's collateral damage one time and the effect does not get continually added to the antipathy level each turn.

Attack influence is caused by an insurgent attack and placed on the terrain surrounding an attack. This represents the amount of the loss in trust in the government that occurs for a civilian when an insurgent attacks. By seeing that the government does not have total control over the area and the lack of security, a civilian loses some trust in the government. Attack influence also decays over time according to an exponential decay function. For attack influence, any civilian can only be affected by an attack's influence one time and the effect does not get continually subtracted from the trust in government level each turn.

Asset influence is added to the terrain whenever a government asset is nearby. When a civilian moves within the asset influence radius of any government asset, the civilian gains trust in government stored by that terrain agent. Asset influence remains as long as the asset remains and is added to the civilian's trust in government each turn that it is detected.

During a turn, each terrain agent operates according to the following set of rules.

1. Check to determine if coalition collateral damage (*coalition_collateral_damage*) is greater than zero.
   a. If coalition collateral damage is greater than zero, then decay that damage. Coalition collateral damage cannot be negative.
   b. If coalition collateral damage is equal to zero, do nothing.
2. Check to determine if insurgent collateral damage (*insurgent_collateral_damage*) is greater than zero.
   a. If insurgent collateral damage is greater than zero, then decay that damage. Insurgent collateral damage cannot be negative.
   b. If insurgent collateral damage is equal to zero, do nothing.
3. Check to determine if attack influence (*insurgent_attack_influence*) is greater than zero.
   a. If insurgent attack influence is greater than zero, then decay that influence. Insurgent attack influence cannot be negative.
   b. If insurgent attack influence is equal to zero, do nothing.

The next step in this research is to determine quantitative values to represent qualitative research. This stands as one of the biggest challenges in all social science modeling – how do you quantify parameters and characteristics that are inherently subjective and difficult to quantify?

In this study, the level of a civilian's antipathy toward the Afghan central government is the determining factor of whether a civilian joins or resists the insurgency. A civilian starts with a random amount of antipathy at the beginning of this simulation. While for this model antipathy is a random amount, using actual survey data collected from talking to the people of Afghanistan could produce a more representative model. During each turn of the simulation, based on the events and actions that occur within the simulation, an updated calculation for each civilian's antipathy is performed. If upon this calculation that civilian's antipathy is above the established threshold (*antipathyThreshold*), that civilian joins the insurgency. The factors that contribute to the antipathy calculation are a civilian's trust in government (*trust_in_government*), coalition collateral damage caused (*coalition_collateral_damage*), insurgent collateral damage caused (*insurgent_collateral_damage*), the fact that coalition troops are present within Afghanistan (*coalitionPresenceAntipathyAdd*), and tribal factors, such as affiliation and isolation (*tribalAntipathyAdd*). The next step is to determine a numerical value that each of these factors contribute to the antipathy calculation.

Table 2. Contributing factors to antipathy and their rank.

Factor	Ranking
Trust in Government	1.0
Coalition collateral damage caused	0.8
Coalition troops present	0.6
Insurgent collateral damage caused	0.4
Tribal factors	0.1

This was done by creating a weighted scale ranging from 0 to 1. Each factor was then scored on the weighted scale according to its importance as supported by the above and following discussion. The weighting factors were assigned as shown in Table 2. The equation for determining a civilian's overall antipathy is

$$A_{t+1} = A_t + (0.6 \times A_{\text{Coalition}}) + (0.8 \times A_{\text{C Collateral}}) + (0.1 \times A_{\text{Tribal}}) - (0.4 \times A_{\text{I Collateral}}) - \textit{trust\_in\_government}$$

The numbers were assigned after conducting research on the factors contributing to the insurgency. For each factor ranked, the following is the justification.

2.2.9 Tribal factors. Tribal factors represent the often contentious and complex issue of tribal dynamics and interactions. Afghanistan's history has been written and interwoven among the tribal and ethnic disputes and conflicts that have existed for as long as there has been a country. The four primary ethnic groups within Afghanistan are the Pashtuns, the Tajiks, the Uzbeks, and the Hazaras, making up 99% of the population. Within these ethnic groups are hundreds of tribes and sub-tribes. These different ethnic groups, tribes, and sub-tribes combine to form a volatile mix.

Rais[8] states that the Afghan people are more aware and sensitive to their ethnic and tribal differences today than at any time in the country's history. As a result of the successful expulsion of the Soviet Union, the Mujahidin established semi-self governing regions of the country broken down

along ethnic lines. These ethnically divided Mujahidin groups then fought a bloody civil war in pursuit of control of the state. This civil war exacerbated the differences and disputes between the ethnic groups. The rise of the Taliban in the mid-1990s created a largely Pashtun movement attempting through military conquest to bring the country under its control. This movement was opposed by a coalition of Tajik and Uzbek groups.

2.2.10 Insurgent collateral damage. Insurgent collateral damage has an inverse effect on civilian antipathy – as insurgents hurt innocent civilians, their antipathy toward the government is diminished. This is not so much because civilians develop a higher regard for the government, but because they have a growing resistance toward the insurgency. Insurgent collateral damage can take the form of the injury or death of a loved one at the hands of an insurgent attack, the intimidation and threats of insurgents toward one's family, the destruction of assets within a civilian's environment, such as a school or a clinic, or economic damage inflicted by insurgents upon civilians. Another situation that falls under the umbrella of insurgent collateral damage is a situation where the Neo-Taliban tries to pit one community or tribe against another. By doing this, they are deciding to try to recruit one segment and allow the government to secure the other.

According to Giustozzi,[7] 'the Taliban displayed considerable skill in identifying local rivalries and siding with communities opposed to Kabul and its local allies.' However, they experienced problems with this strategy because by using it, they limit their ability to grow their support to include the rival, pro-government communities.

2.2.11 Coalition troops present. Some Afghans join the insurgency based on their belief that foreign troops within Afghanistan is justification for fighting against them. Afghanistan has had a history of fighting and expelling foreign invaders and the insurgency uses this tradition to its advantage in recruiting. Afghan fighters resisted Alexander the Great in the 300s B.C., the British three times in the 18th and 19th centuries, and the Soviet Union in the late 20th century. A Pashtun tribesman summed up this spirit of resistance, telling Mountstuart Elphinstone, a British official visiting Afghanistan in 1809, 'We are content with discord, we are content with alarms, we are content with blood... we will never be content with a master.'[13]

2.2.12 Coalition collateral damage. The damaging and negative effect of United States/NATO collateral damage, especially as a result of air strikes, is found throughout the literature on the insurgency in Afghanistan. Ahmed Rashid[14] in his book 'Descent into Chaos,' indicated that the coalition's heavy reliance on air strikes 'lost any hope of winning over the population.' In May of 2006, 750 air strikes killed an estimated 400 Taliban fighters and Afghan civilians. Rashid recounts a British officer stating that the reliance on air strikes is 'a textbook case of how to screw up a counterinsurgency.' James Dobbins,[15] American President George W Bush's first special envoy for Afghanistan and representative to the Bonn Conference where the new Afghan government was formed, states in his book 'After the Taliban' that an American AC-130 gunship mistakenly killed 48 innocent wedding goers and wounded over 100 others in the summer of 2002. He believes that the United States simply builds resentment and squanders goodwill unnecessarily when it makes these kinds of mistakes.

2.2.13 Trust in government. Trust in government is ranked as the most important factor in the calculation of antipathy. It consists of three contributing factors – the number of Afghan National Army troops present, the number of insurgent attacks that have occurred, and the number of government assets present. For the purposes of this study, these factors encapsulate several important aspects that contribute to the insurgency. These factors include economic well-being and opportunity, security, good governance, health care, clean water, electricity, and education. Two of these factors focus on security.

Both the number of insurgent attacks that have occurred and the number of Afghan National Army troops present speak to the security issue. Having agents of the government present, patrolling, and visible to civilians in any area gives civilians some confidence in their government. Those troops are necessary to secure Afghanistan. Conversely, having insurgents conduct attacks throughout the countryside erodes civilians' confidence and trust in government.

In the calculation of trust in government, the three contributing factors are ranked as shown in Table 3.

The formula for calculating trust in government is as follows, where T is trust in government, T_{Asset} is trust in government added each turn due to government asset being present, T_{Attack} is trust in government lost due to insurgent attack, and T_{ANA} is trust in government added due to Afghan National Army presence:

$$T_{t+1} = T_t + (1 \times T_{\text{Asset}}) + (.75 \times T_{\text{ANA}}) - (.75 \times T_{\text{Attack}})$$

The model contains several random variables that represent the distribution of values that characterize the behavior of these parameters. Table 4 lists these variables, their

Table 3. Contributing factors to trust in government and their rank.

Factor	Weight
Government assets present	1.0
Insurgent attacks	0.75
Afghan National Army present	0.75

Table 4. List of parameter probabilities and their justifications.

***Parameter* – threshold value; justification**
During the simulation, a random number drawn from a uniform distribution was compared against the threshold value to determine the results.
anaCollateralDamageProbability – 0.35; this parameter is the probability that an Afghan National Army unit will cause collateral damage when conducting an attack. The Afghan National Army is a newly created force that lacks the experience, equipment, and technology to be very accurate in targeting. They have been receiving training and advisement from the United States and NATO troops. This gives them a 35% chance to cause some collateral damage upon an attack.
anaHitProbability – 0.4; this parameter is the probability that when attacking, an Afghan National Army unit will score a hit. Because the Afghan National Army is a newly created force that lacks experience, equipment, and technology, they have a fairly low accuracy. They have a 40% chance to hit their target.
assetDefenseProbability – 0.01; this parameter is the probability that when defending itself, a government asset will destroy an attacking insurgent unit. To validate the model, this value reflects a situation of little to no security and is set at 1%. This value will be increased as part of a surge scenario.
coalitionCollateralDamageProbability – 0.15; this parameter is the probability that a coalition unit will cause collateral damage when conducting an attack. The coalition forces are well trained, well led, well supplied, and have experience. In addition, they have access to sophisticated targeting technology for most of their weapon systems (laser guided munitions, GPS guided munitions, thermal sights, advanced combat optics for individual weapons) that assist in accuracy. This targeting skill leads to a smaller chance (15%) of causing collateral damage.
coalitionHitProbability – 0.7; this parameter is the probability that when attacking, a coalition unit will score a hit. The coalition forces have proven their ability during the global war on terror to be skilled at destroying insurgent targets. They possess the training, the equipment, the technology, and the experience to be very accurate in hitting their target.
insurgentAnaHitProbability – 0.35; this parameter is the probability that when attacking an Afghan National Army unit, an insurgent will score a hit. Insurgents within Afghanistan are poorly trained, possess poor equipment, and are poorly led in most cases. Marksmanship is almost non-existent within the insurgent forces, which leads to their probability to hit a target being low.
insurgentAssetHitProbability – 0.6; this parameter is the probability that when attacking a government asset, an insurgent will score a hit. For validation that provides little to no security for government assets as they are created, this value is set at 60%. Because insurgents are not always effective and often inaccurate, this value is not higher.
insurgentCollateralDamageProbability – 0.5; this parameter is the probability that an insurgent unit will cause collateral damage when conducting an attack. While the Neo-Taliban attempted to 'manage violence and to target it carefully' in order to win the hearts and minds of the Afghan civilian population, 'unwanted civilian casualties were unavoidable, not least because of the weak technical proficiency of the insurgents.'[7]
insurgentCoalitionHitProbability – 0.03; this parameter is the probability that when attacking a coalition unit, an insurgent will score a hit. Insurgents have low training, poor to average leadership, poor to average equipment, and less than sophisticated targeting capabilities. When compared to the coalition forces military proficiency, insurgent forces are considerably less effective. When attacking a coalition unit, an insurgent unit only has a 3% chance to hit and kill.
insurgentPrtHitProbability – 0.35; this parameter is the probability that when attacking a Provincial Reconstruction Team, an insurgent will score a hit. Provincial Reconstruction Teams have inherent defense but it is relatively small. Insurgents, due to their level of training and proficiency, have a 35% chance of hitting a Provincial Reconstruction Team.
qrfHitProbability – 0.65; this parameter is the probability that when attacking an insurgent unit, a quick-reaction force unit will score a hit. This probability is high because a quick-reaction force is typically called in to the site of an attack that is currently occurring. They arrive with the full focus of some command element that usually has control of many combat multipliers, such as indirect fire support, close air support, or helicopter close air support.

NATO: North Atlantic Treaty Organization, GPS: global positioning system

threshold values, and a justification of the values used within the model.

2.3 Model validation

Prior to using the model to assess the surge questions posed in this research, the model parameters had to be adjusted to calibrate its performance against known results. This validation began by comparing the number of insurgents in the model with the number of insurgents estimated to be within a portion of the Khost province. Based on the estimated number of 5500 insurgents within Afghanistan in 2002 by Giustozzi,[7] it was determined that scaled to the 50 square kilometers of the Khost province, there should be between one and two insurgents within the modeled area. Giustozzi[7] also estimated that in 2006 there were 19,000 insurgents within Afghanistan. Scaled to the modeled area, that number should grow between

four and five insurgents in a four-year period. Therefore, a model that starts with one or two insurgents and runs for a length of time simulating four years of real time should show approximately four to five insurgents at the end of the simulation.

Three parameters were manipulated to achieve this calibration: *Asset Defense Probability*, *Insurgent Asset Hit Probability*, and *Prt Work Cycle*. These parameters were chosen because of the direct effect that Provincial Reconstruction Team presence would have on each one. Specifically, asset defense probability for the model validation was chosen as 1% and the insurgent hit probability when attacking an asset was chosen as 60% to represent the fact that assets have been, without a surge, lightly guarded and without appreciable security. Insurgents who want to attack and destroy government assets face little to no opposition. In addition, the Provincial Reconstruction Team work cycle was set to 60 days. This value represents the fact that even though there is one team within the Khost province, it only works within the modeled area about half of the time. This means that if a Provincial Reconstruction Team is left alone by insurgents, a new government asset is created about every 60 days.

Other important values in the calibration run were the distributions from which the values of attack influence and collateral damage were drawn. Table 5 shows the distributions used for these variables. The distributions were chosen based on subject matter expertise assessments of their characteristics.

For calibration, 30 simulation runs were conducted and statistically analyzed to arrive at these calibration values so as to produce results that matched the real-world estimates. The test was set up as follows:

H_o: mean number of insurgents of sample = researched value of insurgents;
H_a: mean number of insurgents of sample ≠ researched value of insurgents.

Table 5. Distributions used for model validation.

Parameter	Distribution	Mean	Standard deviation
Insurgent attack influence	Normal	0.75	0.05
Insurgent collateral damage	Normal	0.25	0.05
Coalition collateral damage	Normal	0.75	0.005
ANA collateral damage	Normal	0.25	0.05
QRF collateral damage	Normal	0.5	0.005

ANA: Afghan National Army, QRF: quick-reaction force

The test statistic value used to make this comparison was

$$z = \frac{\bar{x} - \mu_0}{\sigma / \sqrt{n}}$$

where $\bar{x}$ is the sample mean, μ_0 is the researched value for number of insurgents, σ is the sample standard deviation, and n is the sample size.

The rejection region for a level α test for the given alternative hypothesis is either

$$z \geq z_{\alpha/2} \text{ or } z \leq z_{\alpha/2}$$

The resultant values of the validation simulation run are shown in Table 1.

The test conducted was a two-tail test with a significance level of 0.05. The value that captures the two-tailed area is 1.96 ($z_{.025} = 1.96$). For the researched value for the number of insurgents being four ($\mu_0 = 4$), the calculated *z*-value for the validation run results was 0.752. With this value, at a 0.05 level of significance, the null hypothesis cannot be rejected. This indicated that the model's performance appeared to match that of the real-world estimates. That is the model ended after four years of simulation time with 4.3 insurgents present in the environment. The research indicated that there should be between four and five insurgents in the modeled area after four years.

3. Simulating the surge with a focused security effort

The next step is to implement the parameters that create a simulated surge using the calibrated model. To simulate a surge within the model, the Provincial Reconstruction Team work cycle was shortened from 60 days to 30 days, the government asset defense probability was increased from 1% to 65%, and the insurgent asset hit probability was decreased from 60% to 15%. These values represent a fourfold increase in coalition and Afghan troop presence within Afghanistan, from the pre-surge number of 101,000 troops to a total of 404,000 troops. This fourfold increase would cut the insurgent effectiveness against the government assets by 25% and increase the asset defense probability from basically zero to 65%. It increases the number of Provincial Reconstruction Teams that would work within the Khost province as part of a surge and the platoon-sized troop elements that would be stationed with and securing government assets created. The troops securing the assets would both raise the defense capability of the asset and decrease the likelihood of a successful insurgent attack.

Using these surge parameters, the simulation ran for four years per iteration, for 30 iterations. The only difference in the model calibration runs and the surge runs are the three aforementioned parameters of *Asset Defense Probability*,

Prt Work Cycle, and *Insurgent Asset Hit Probability*. To measure the results of the simulation, the number of insurgents in the environment at the end of each four-year run was recorded.

This is followed by determining if the implemented surge of four times the current troop strength is effective at reducing the number of insurgents. A comparison of means using the mean of the non-surge validation runs and the surge runs was conducted. If the means of the two samples are equal, it indicates that the surge would be no more effective than the non-surge strategy. The surge scenario must also be tested to see if the number of insurgents at the end of the four-year run is less than the number of insurgents in the validation, non-surge scenario. A surge scenario that has a mean less than the mean of the validation run could be termed as a success, in that it reduced the growth of the insurgency.

Because both sample sizes were large and their variances were known, the test statistic used to determine if the means of the two samples were equal, as shown below:

$$\bar{x} - \bar{y} \pm z_{\alpha/2}\sqrt{\frac{s_1^2}{m} + \frac{s_2^2}{n}}$$

where $\bar{x}$ is the mean of the validation runs, $\bar{y}$ is the mean of the surge runs, α is the confidence level of the test measured by $100(1 - \alpha)$, s_1^2 is the sample variance of the validation runs, s_2^2 is the sample variance of the surge runs, *m* is the sample size of the validation runs, and *n* is the sample size of the surge runs.

Table 6 shows the values for the surge runs and the parameters used in the test statistic.

Using these values yielded the following 95% confidence interval: (1.10, 3.04). This confidence interval does not contain zero, and therefore suggests that the means are not equal. Because this interval is positive, it suggests that the mean number of insurgents at the end of the surge runs ($\bar{y}$) was smaller than the number of insurgents at the end of the calibration runs ($\bar{x}$). This suggests that there would be fewer insurgents after implementing a surge strategy than there were after the current strategy implementation. These results reflect the potential outcome of a surge four times the current force size in Afghanistan (101,000 surged to 404,000 troops). If a large fourfold surge of troops might bring success to the counterinsurgency in Afghanistan, what results would a surge of two times the number of current troops produce? How about a surge of only 50,000 troops?

Table 6. Mean comparison values for fourfold surge.

Parameter	Value
Sample size of surge (*n*)	30
Sample mean of surge ($\bar{y}$)	2.23
Surge sample variance (s_2^2)	2.60
Validation sample size (*m*)	30
Validation sample mean ($\bar{x}$)	4.3
Validation sample variance (s_1^2)	4.8
α corresponding to a 95% confidence interval (C.I.)	0.05
z-statistic for 95% C.I.	1.96

Table 7. Surges: successful or not?

Type of surge	Confidence interval	Successful surge?
Fourfold troop increase (surge 303,000)	(1.10, 3.04)	Yes
Double current troop strength (surge 101,000)	(0.02, 4.12)	Yes
50% increase in current troop strength (surge 50,000)	(–2.72, 1.65)	No

To determine the minimum size troop surge that might bring success in Afghanistan, two more 30-run simulations were devised and implemented. The first of the two runs simulated a surge of double the current troop strength. The parameters that reflect a doubling of the current troop strength from 101,000 to about 202,000 troops would be an *Asset Defense Probability* of 32.5% and an *Insurgent Asset Hit Probability* of 30%, with all other parameters and variables remaining the same. For a 50,000 troop surge, or a 50% surge, the *Asset Defense Probability* and *Insurgent Asset Hit Probability* parameters changed to 16.25% and 45%, respectively. The results of these surge runs can be seen in Table 7.

As indicated by Table 7, a surge of troops that increases the coalition force size to roughly 200,000 troops produces a mean of insurgents that is not statistically equal to the mean of insurgents from the simulation implementing the current strategy in Afghanistan. The results indicate that the mean of insurgents after four years of a 200,000 troops surge (roughly 100,000 troops in addition to the current 100,000 on the ground) is less than the mean of the current strategy. In addition, Table 7 indicates that a troop surge of only roughly 150,000 troops (50,000 additional troops) produces a mean of insurgents that is not statistically different than the results of the current strategy implementation.

In summary, three different surge scenarios were implemented using the validated model. A surge of 400,000 or 200,000 troops provides evidence that these troop levels reduce the mean number of insurgents when compared to the current strategy. A surge of 150,000 troops provides no evidence that it would produce a mean number of insurgents

that is any different than the mean number of insurgents produced by the current non-surge strategy.

4. Conclusion

The purpose of this study was to provide a means of assessing if the implementation of a military troop surge designated toward a focused security effort strategy might reverse the trend of the growing insurgency in Afghanistan. The strategy using the United States/coalition/Afghan National Army troop strength of about 101,000 soldiers has failed to defeat or even stop the growth of the Neo-Taliban insurgency. This research sought to add some insight into whether or not a surge with a specific role could work within Afghanistan.

An agent-based model was developed to represent the factors and dynamics that contribute to the insurgency in Afghanistan. Extensive qualitative research was used to develop the model, determining the agents, their rules, and interactions. This qualitative research was then mapped to quantitative values for use within the developed model. In addition, a strategy of a focused security effort was devised. This strategy focused surge troops on the securing of government-enhancing assets created by Provincial Reconstruction Teams rather than assigning them the mission of kill or capture insurgents. The model was calibrated using data provided in the research pertaining to the number of insurgents within Afghanistan. Using the calibrated model, parameters reflecting a troop surge using a focused security effort were implemented. The results of these experiments indicated that a surge of 400,000 or 200,000 troops will reduce the size and strength of the insurgency, but a surge of 150,000 troops would not. These results are not definitive or absolute, but give insight into the possible outcomes of a surge of the given size based on a model built using careful research. This research represents a tool for analysis in the decision process to determine if a surge should occur. It is not the answer to the question of whether a surge would be effective.

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